



Jet Propulsion Laboratory
California Institute of Technology

AI for the future of first responders

Kyongsik Yun, Ph.D.

Bio-Inspired Technologies and Systems Group, NASA Jet Propulsion Laboratory

kyongsik.yun@jpl.nasa.gov

CIRI International Workshop on AI

December 2017

* The research described in this presentation was carried out at the Jet Propulsion Laboratory, California Institute of Technology and was supported in part by the U.S. Department of Homeland Security, Science and Technology Directorate under NASA prime contract NAS7-03001, Task Plan Number 82-106095 and 82-106056

** Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not constitute or imply its endorsement by the United States Government or the Jet Propulsion Laboratory, California Institute of Technology.

© 2017 California Institute of Technology. Government sponsorship acknowledged.



Jet Propulsion Laboratory
California Institute of Technology

Next generation first responder

Protected by chemical, biological, gas, body/air temperature, heart rate, accelerometer, video, audio sensors

Connected to peers and commanders by personal area network, bluetooth, commercial cell network, satellite communications

Fully aware of building schematics, traffic cameras, CCTV, local hospital directions, collaborative next steps, geographical information, plume model, vehicle/staff information, hydrant location



Jet Propulsion Laboratory
California Institute of Technology

Data overload for first responders

Overwhelming data prevents first responders from performing their critical activities



Working memory holds information for a few seconds. It's temporary



Working memory can hold only five to seven items at a time. It has a small capacity



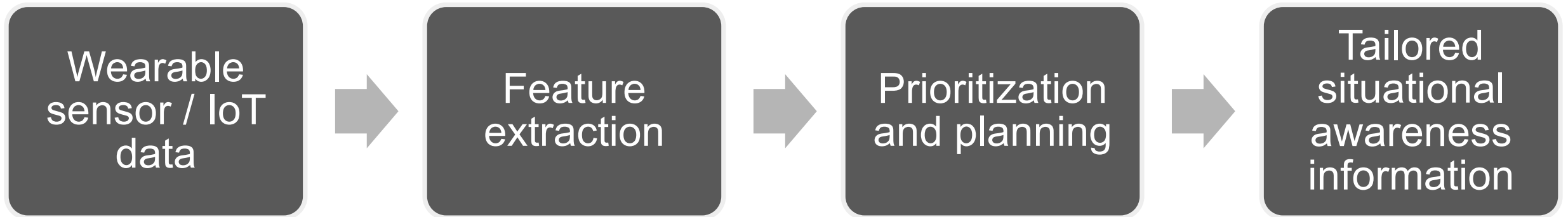
Working memory manipulates information



Jet Propulsion Laboratory
California Institute of Technology

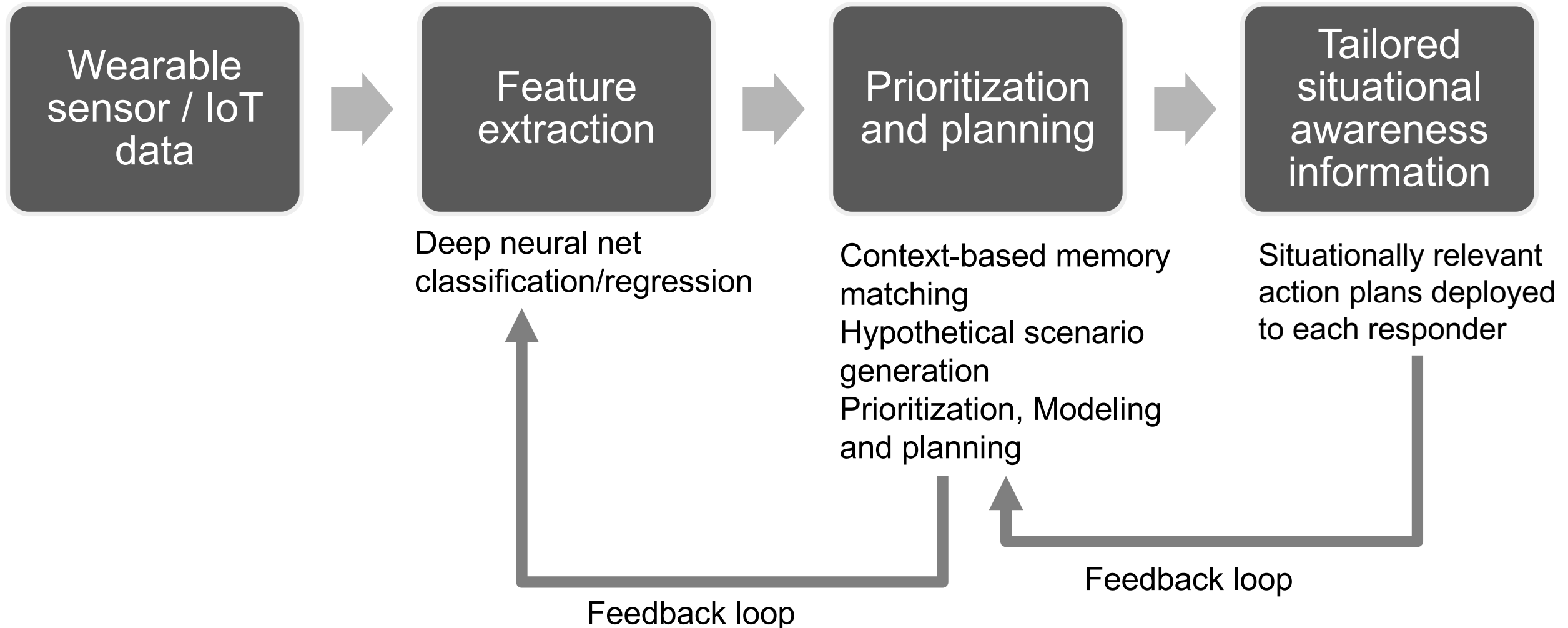
Transforming data into insight

Apply JPL's state-of-the-art human-like reasoning system Assistant for Understanding Data through Reasoning, Extraction, and Synthesis (AUDREY) to perform data fusion and provide tailored situational awareness information to first responders





AUDREY is an integrated platform for transforming multimodal data into contextually relevant insight





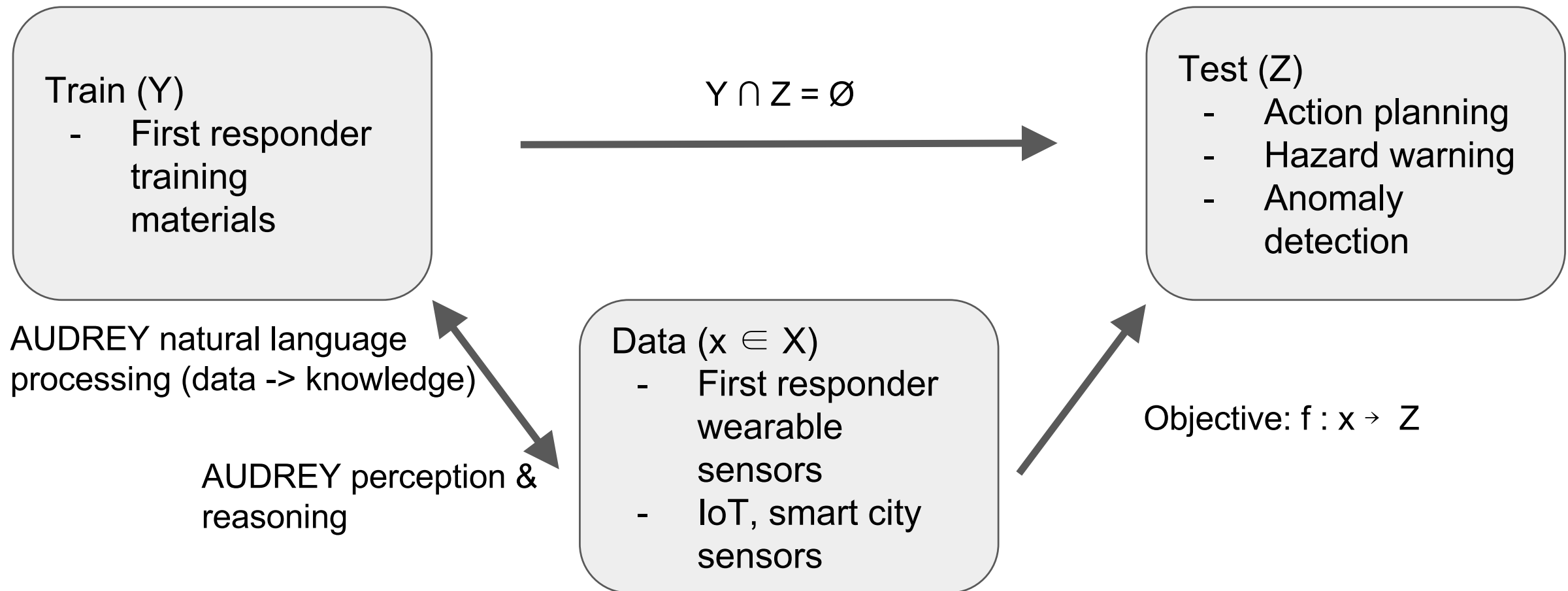
AUDREY (Assistant for Understanding Data through Reasoning, Extraction, & sYnthesis)

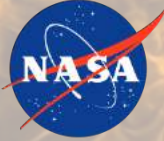
- Uses bio-inspired hybrid neural network and symbolic reasoning
 - training large neural networks with objects, relationships, and dynamics
 - building symbolic models based on deep and organized representations
- Capabilities:
 - Simultaneously perform inference and learning in real time
 - Deal with missing or contradictory data
 - Automatically synthesize workflows to answer questions



How does AUDREY deal with complex unknown situations?

AUDREY zero-shot learning





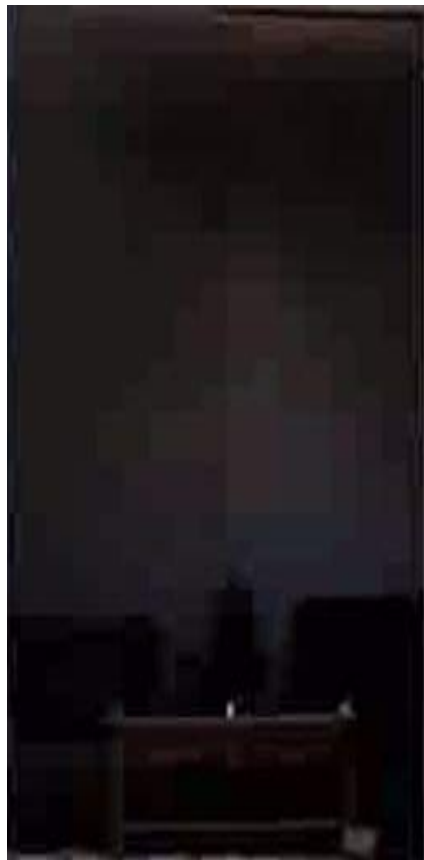
Jet Propulsion Laboratory
California Institute of Technology

AUDREY object detection, tracking, and reasoning for flashover prediction

- Flashover is an instance of a fire spreading very rapidly across a gap because of intense heat
- Flashover is the most-feared phenomenon among firefighters
- Indicators: thick dark smoke, high heat, rollover (angel fingers) -> color, size, shape
- Planning, collaboration to attack at the right timing is the key



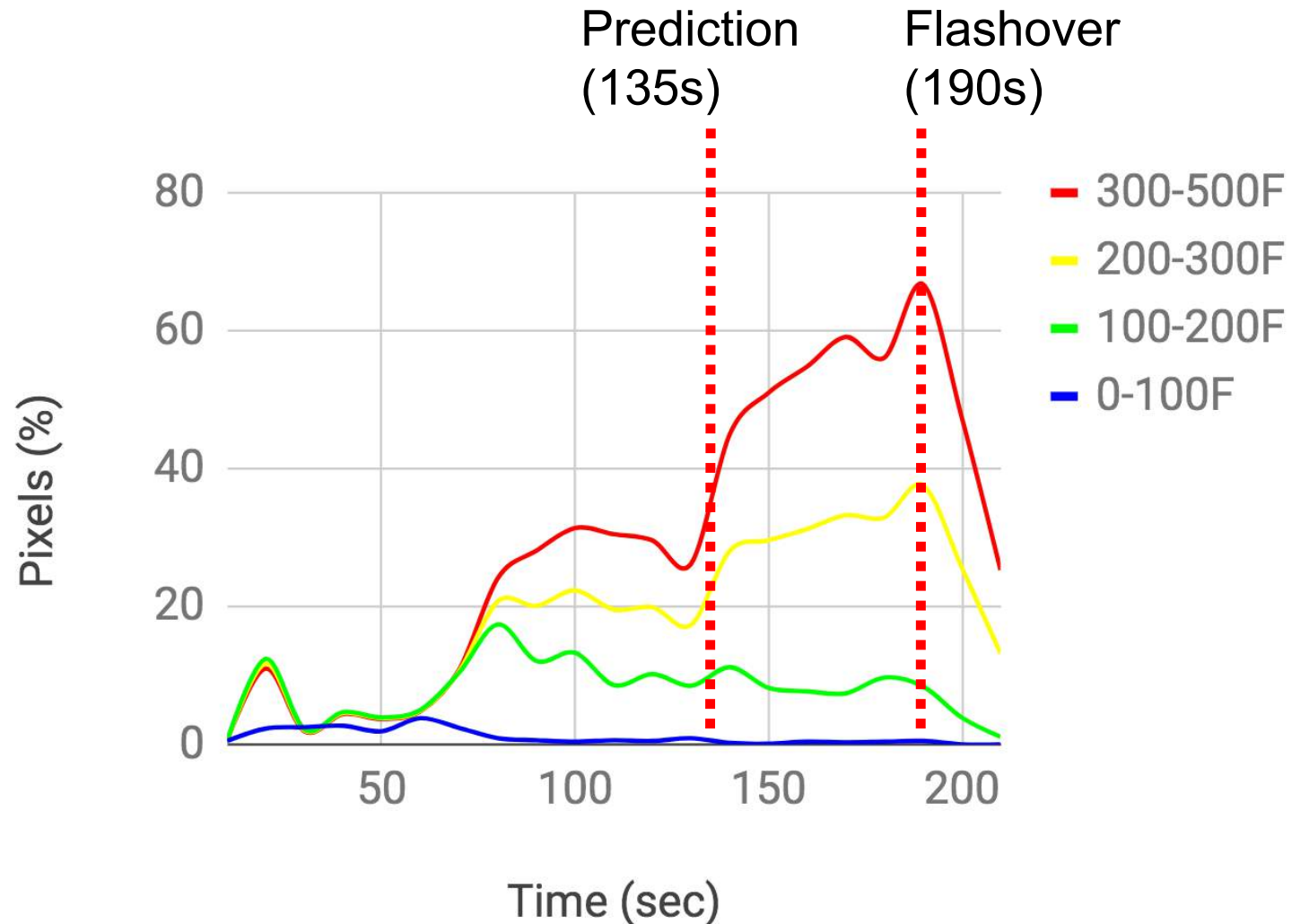
AUDREY can analyze temporal changes of smoke and fire to predict rapid fire growth (flashover)



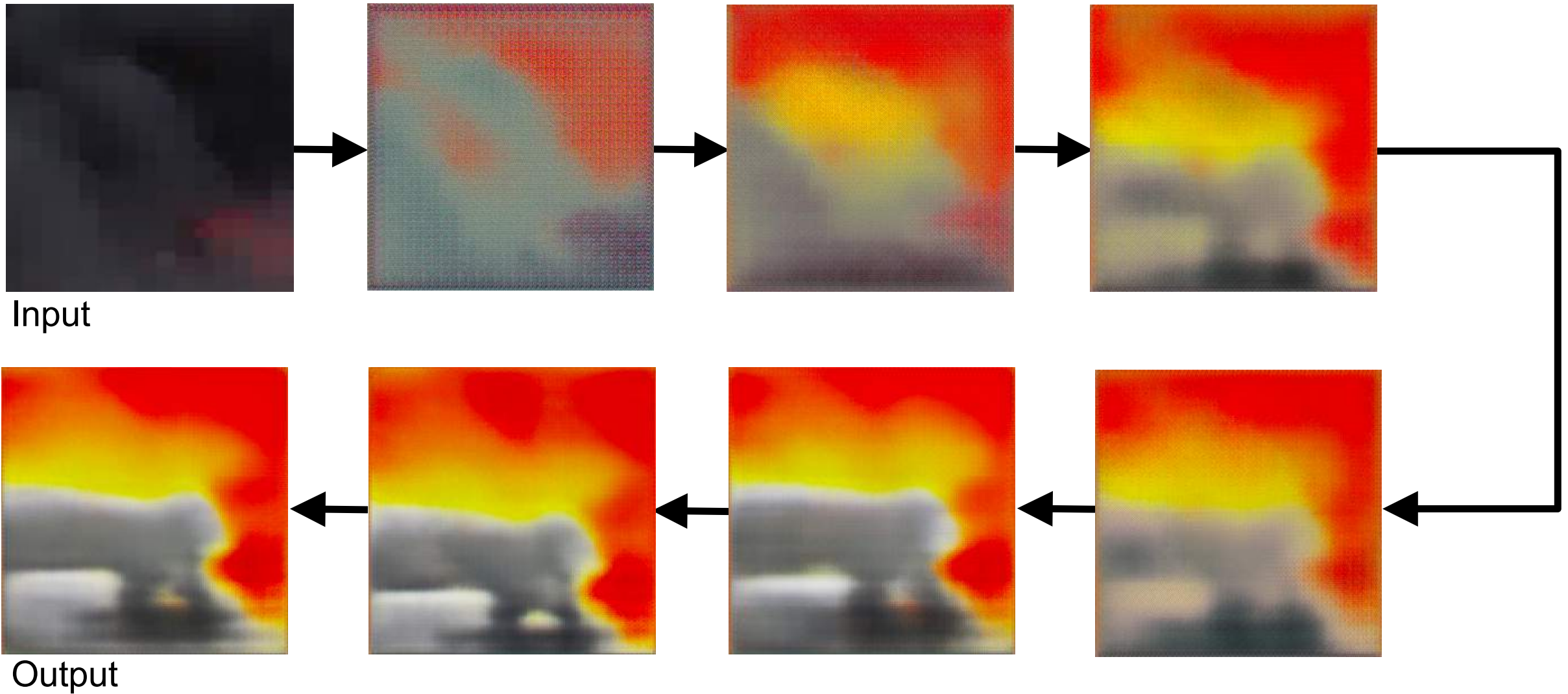
Original video



Enhanced video



Feature extraction and human-like reasoning for image enhancement





Jet Propulsion Laboratory
California Institute of Technology

Occluded object reconstruction for first responders with AR glasses



Input image



Reconstructed image



Augmented image



Generative deep neural net



Input + Reconstructed overlay

Distributed AUDREY agents for search and rescue mission



Collaboration among multiple AUDREY agents for high-resolution video analysis

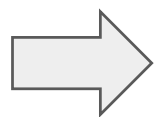
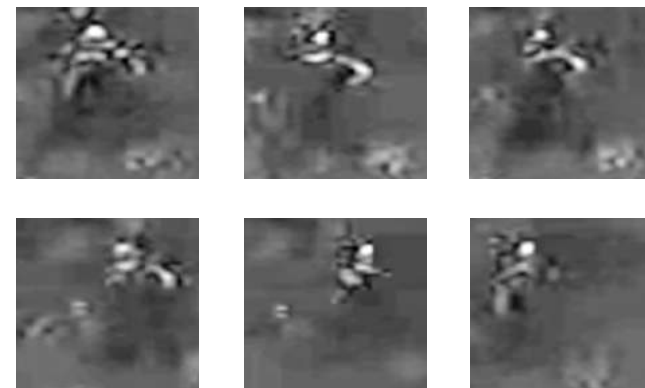
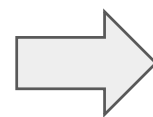


Image contrast enhancement



Training small features

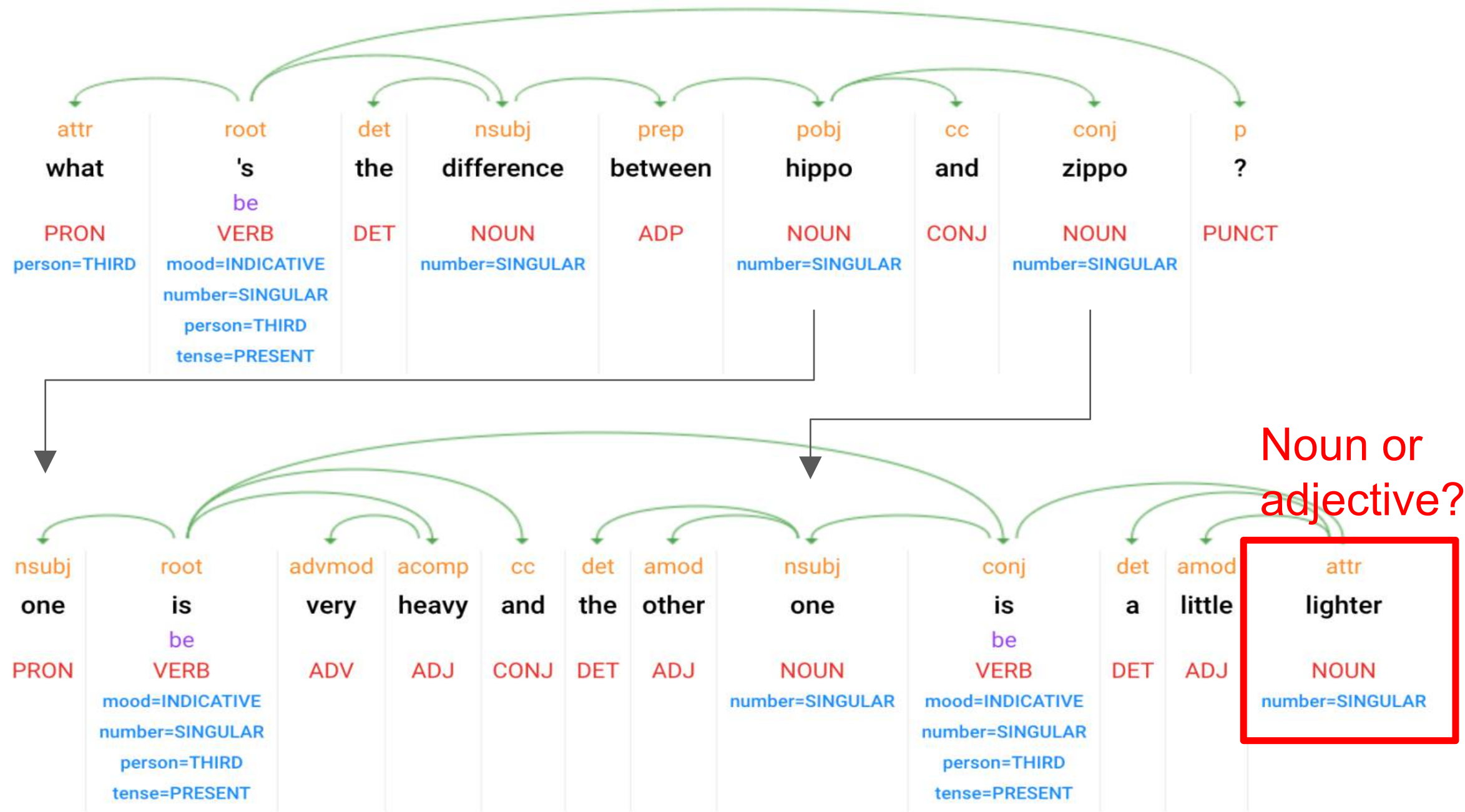


Recognizing small humans

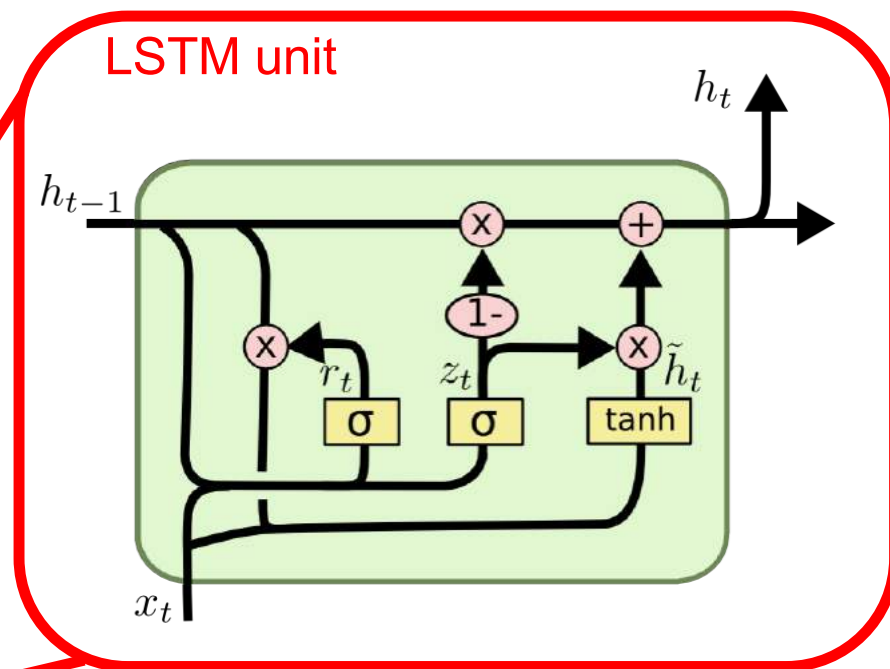
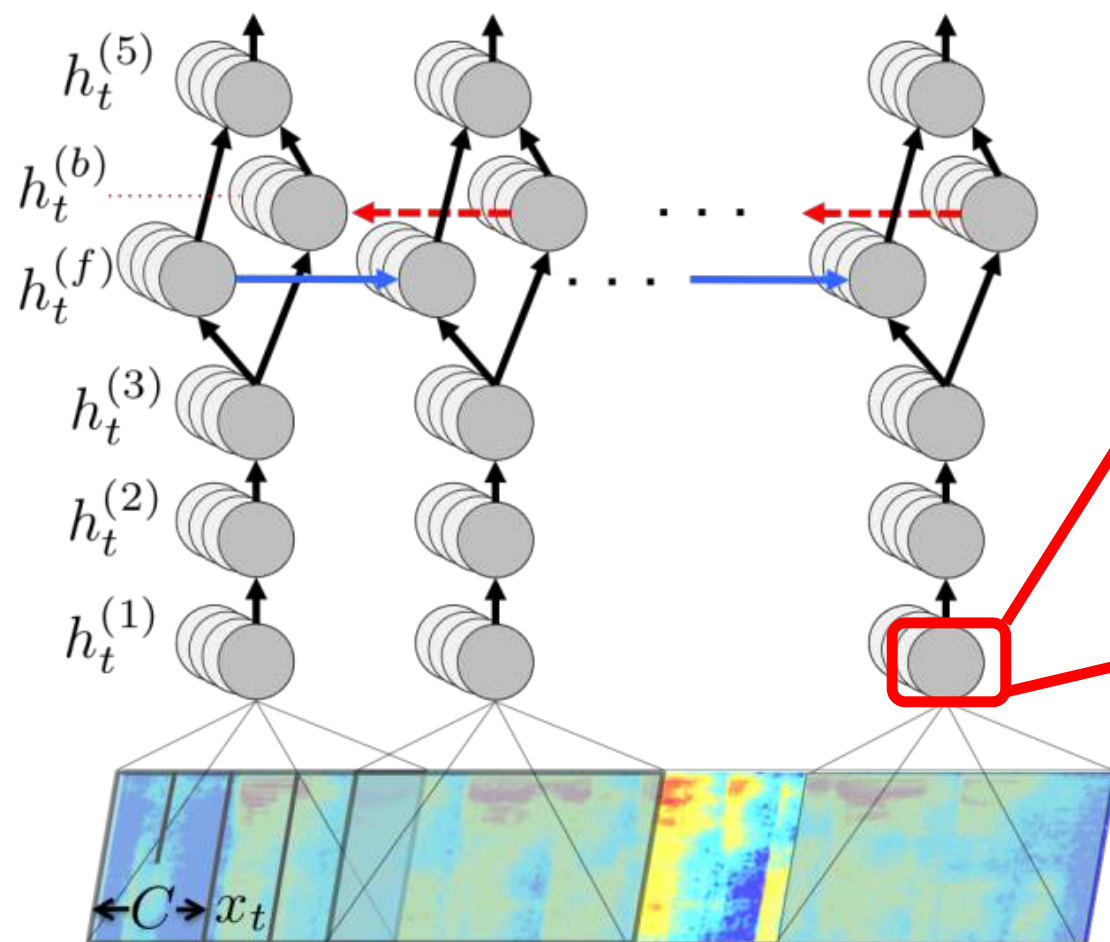
Small human detection in UAV



Contextual understanding of long-term dependencies in human language



Recurrent neural network for long-term dependencies in human language



$$z_t = \sigma(W_z \cdot [h_{t-1}, x_t])$$

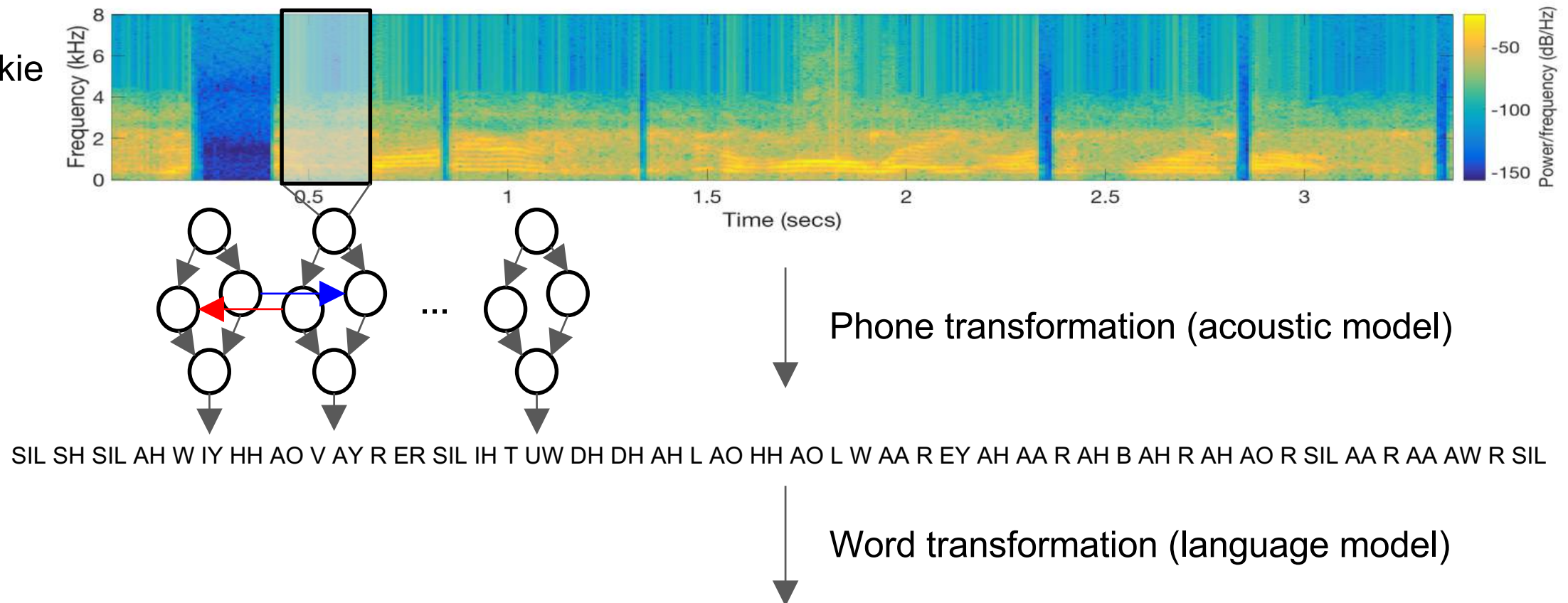
$$r_t = \sigma(W_r \cdot [h_{t-1}, x_t])$$

$$\tilde{h}_t = \tanh(W \cdot [r_t * h_{t-1}, x_t])$$

$$h_t = (1 - z_t) * h_{t-1} + z_t * \tilde{h}_t$$

Firefighter communication in noisy environment

Noisy walkie-talkie audio

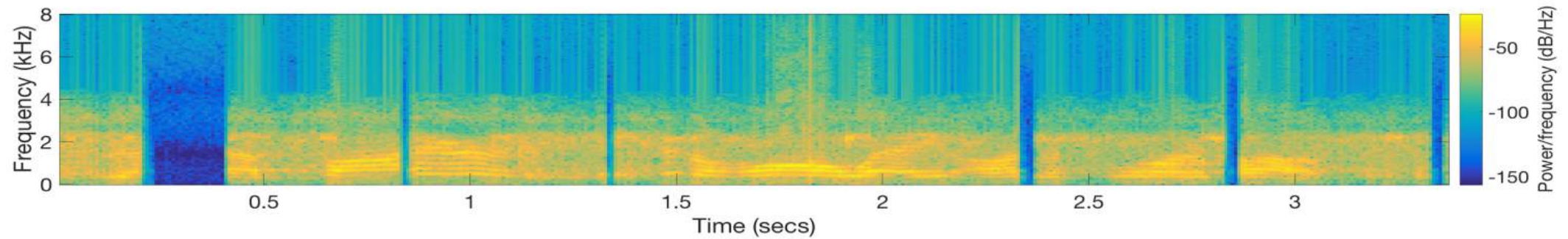


We have fire into the hallway on the floor above

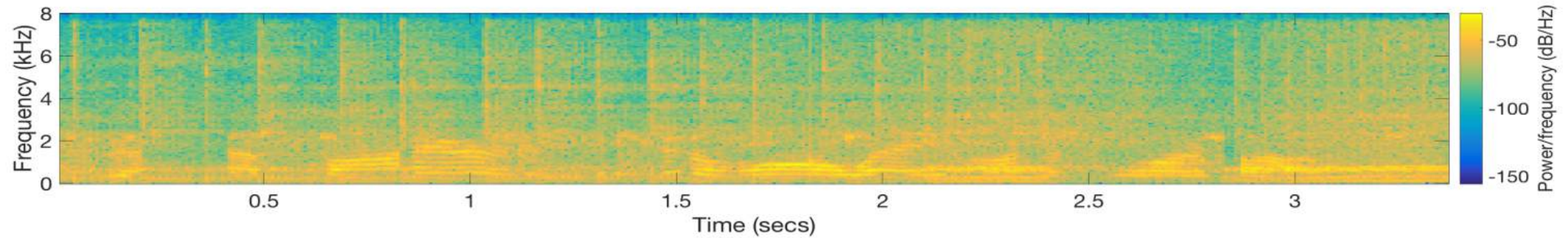


Firefighter communication in noisy environment

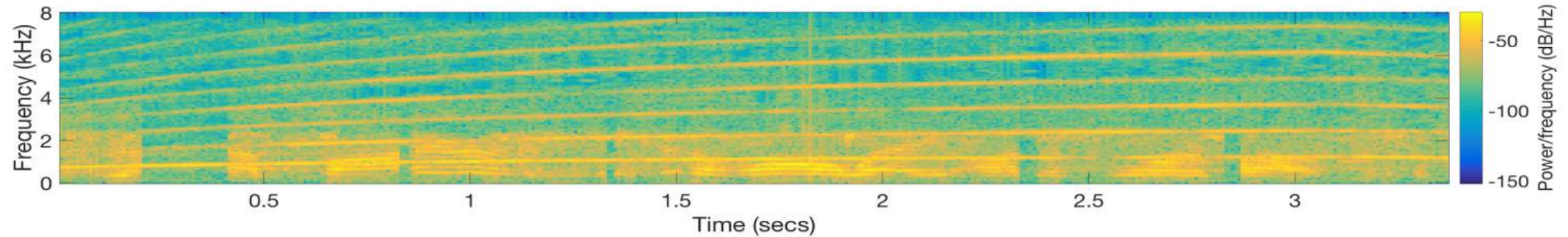
Noisy walkie-talkie
audio



+ Chainsaw

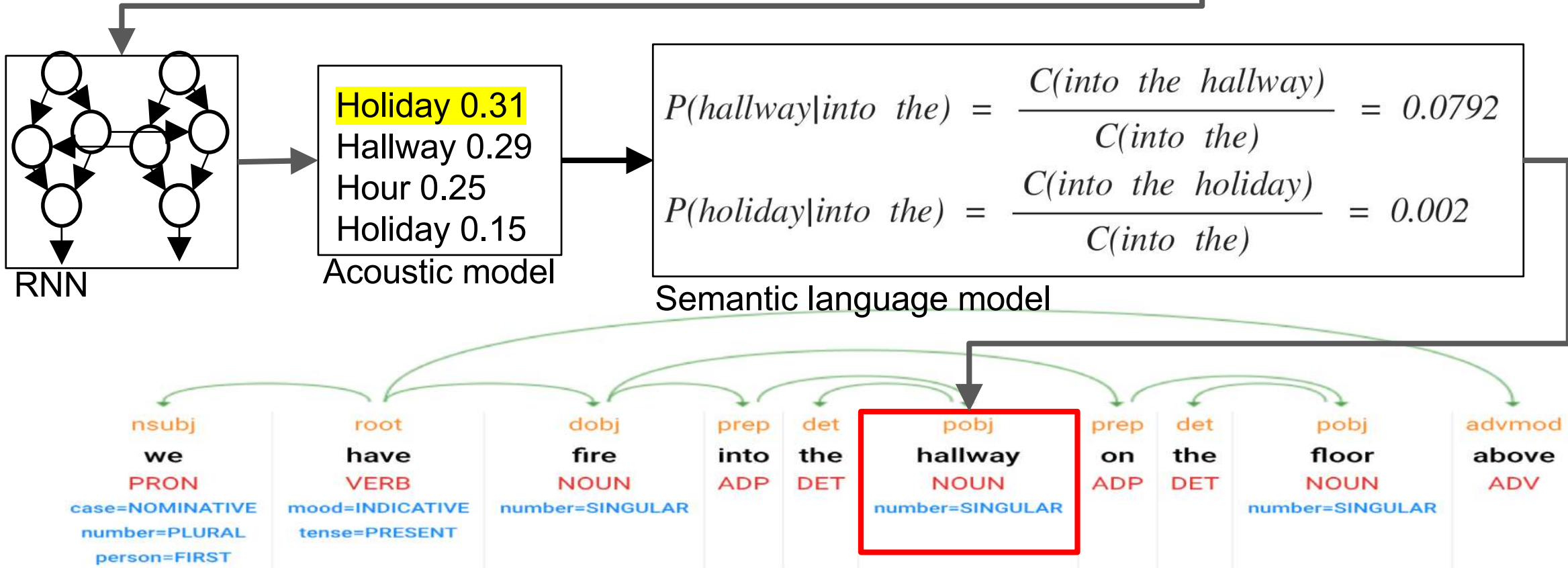
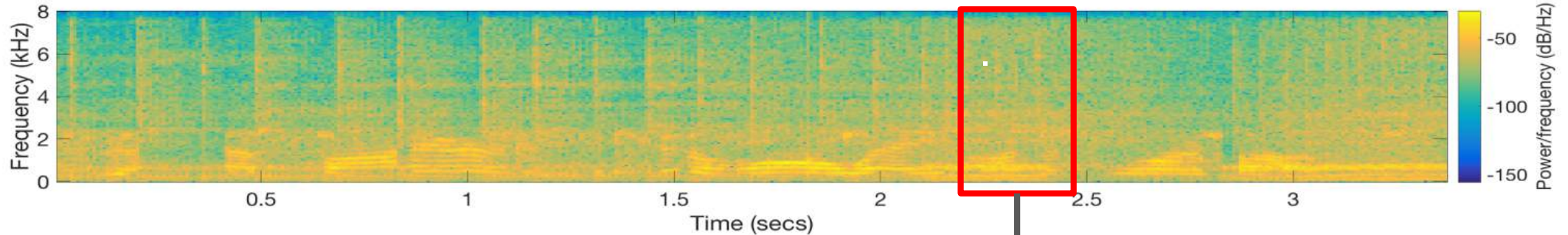


+ Siren



Semantic language processing in noisy environment

Speech
+
Chainsaw





Jet Propulsion Laboratory
California Institute of Technology

Firefighter speech recognition with chainsaw and siren noise

```
firefighter_speech_demo_v0.1 $./firefighter_demo.sh
```

```
listening...
```



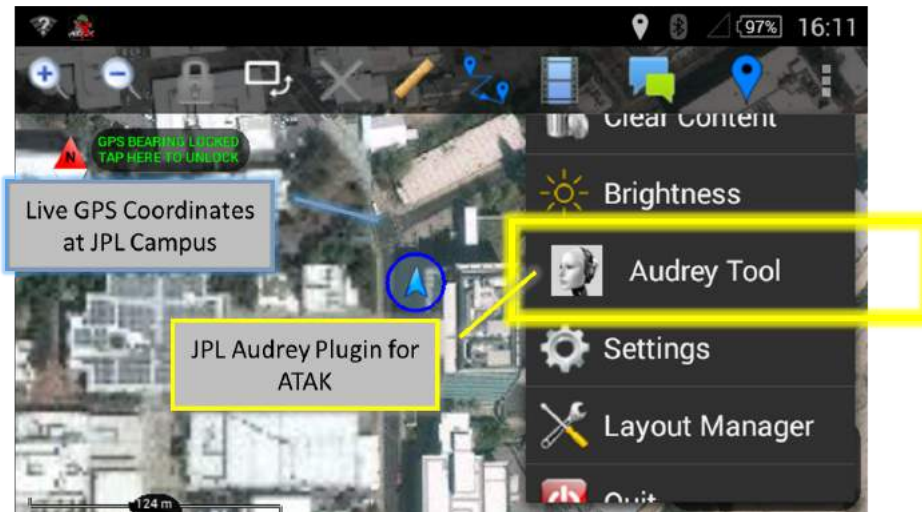
KSC Launch Control Center Speaker/Speech Recognition

 **Jet Propulsion Laboratory**
California Institute of Technology

Android Team Awareness Kit (ATAK) AUDREY Plugin Development

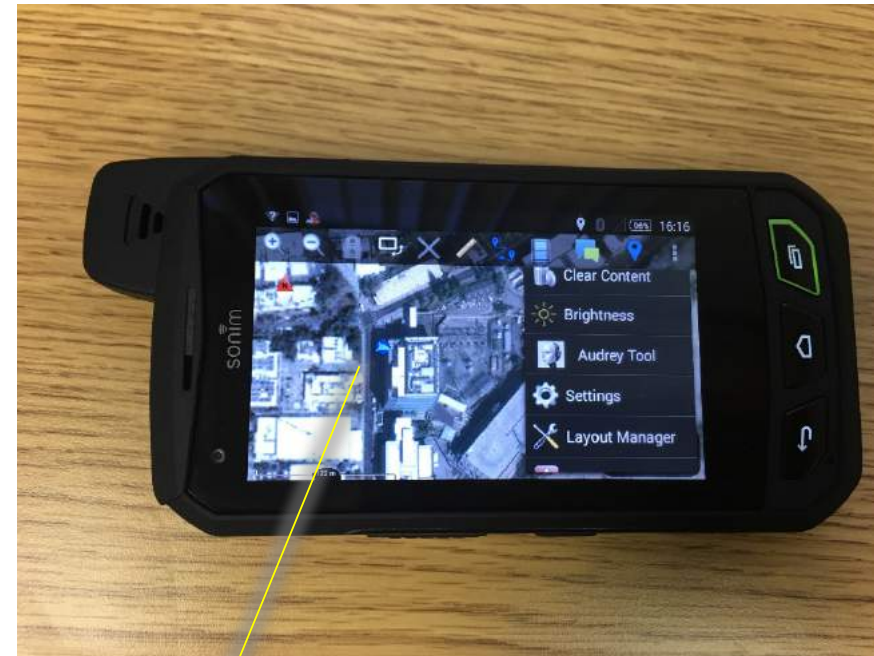
An Android smartphone geo-spatial infrastructure app built using NASA World Wind (virtual globe).
To provide first responders “**up-to-the second understanding of what’s going on around them**”

Audrey Plug-in



Online/offline mapping
Collaborative mapping, precise geo-location
Chat, video sharing, altitude profiling, navigation

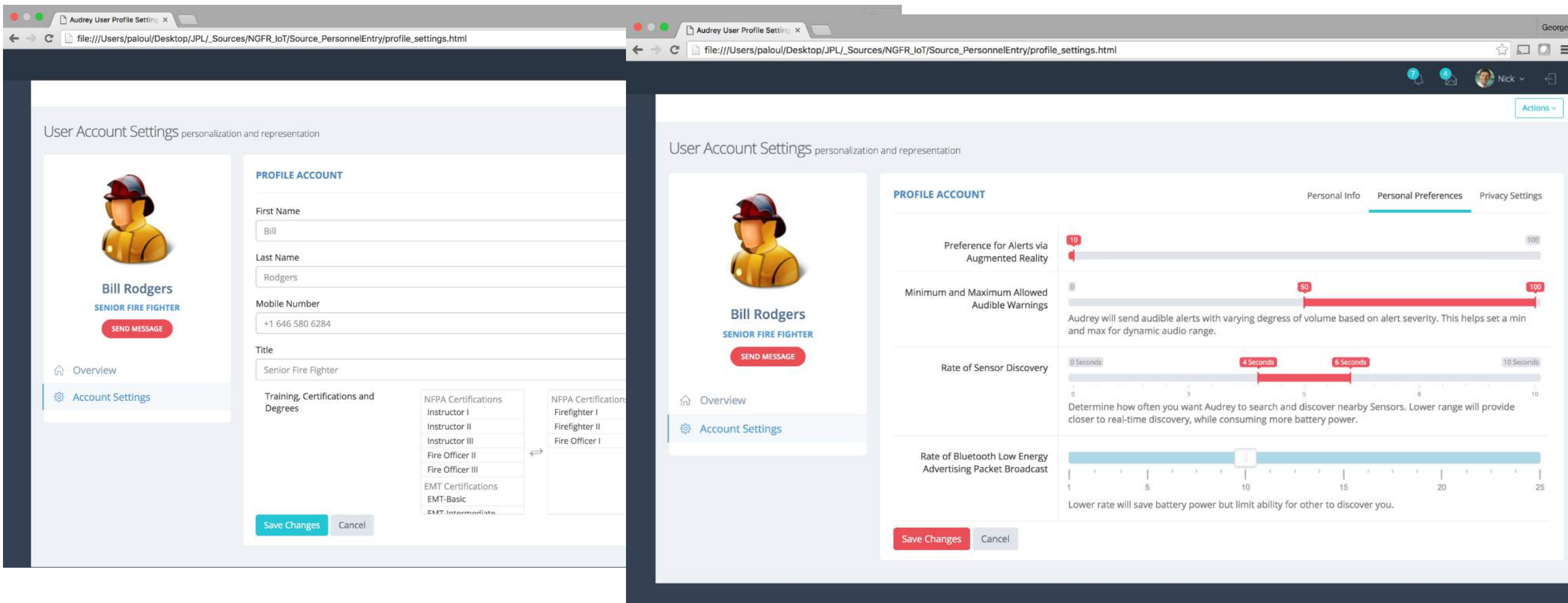
Live Deployment to Android



JPL Campus

AUDREY UI for personalization

Based on the first responder profile and preference, we can provide the situationally relevant action plans for each responder at the right timing.



The image displays two screenshots of the AUDREY User Account Settings interface, illustrating personalization options for a first responder profile.

Left Screenshot (Profile Account Tab):

- User Account Settings** (personalization and representation)
- PROFILE ACCOUNT**
 - First Name: Bill
 - Last Name: Rodgers
 - Mobile Number: +1 646 580 6284
 - Title: Senior Fire Fighter
 - Training, Certifications and Degrees:
 - NFPA Certifications: Instructor I, Instructor II, Instructor III, Fire Officer II, Fire Officer III
 - EMT Certifications: EMT-Basic, EMT-Intermediate
- Actions:** SEND MESSAGE, Save Changes, Cancel

Right Screenshot (Personal Preferences Tab):

- User Account Settings** (personalization and representation)
- PROFILE ACCOUNT**
 - Personal Info
 - Personal Preferences**
 - Preference for Alerts via Augmented Reality: 10 (Scale 0-100)
 - Minimum and Maximum Allowed Audible Warnings: 50 (Scale 0-100)
 - Audrey will send audible alerts with varying degree of volume based on alert severity. This helps set a min and max for dynamic audio range.
 - Rate of Sensor Discovery: 4 Seconds (Scale 0-10 Seconds)
 - Determine how often you want Audrey to search and discover nearby Sensors. Lower range will provide closer to real-time discovery, while consuming more battery power.
 - Rate of Bluetooth Low Energy Advertising Packet Broadcast: 10 (Scale 1-25)
 - Lower rate will save battery power but limit ability for other to discover you.
- Actions:** Save Changes, Cancel



Jet Propulsion Laboratory
California Institute of Technology

AUDREY software technologies

Current AUDREY core software has 1.5 million lines of code

- Government off-the-shelf software
- AUDREY backend system (CORTEX) is based on open source software code
- Fully cloud enabled and completely scalable

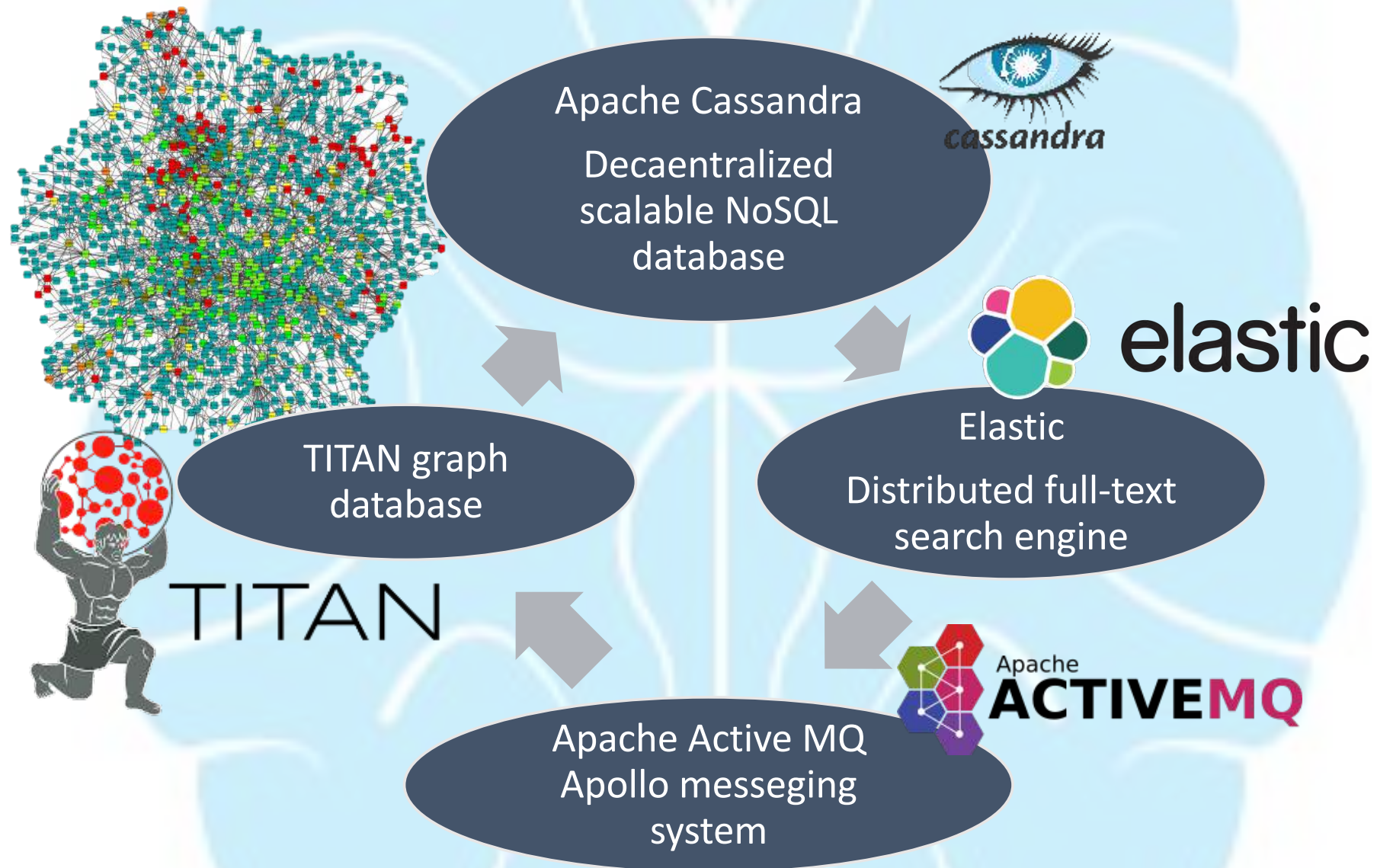
CORTEX

(Categorical Object Repository for Theories and EXperience)



Jet Propulsion Laboratory
California Institute of Technology

CORTEX (Categorical Object Repository for Theories and EXperience)



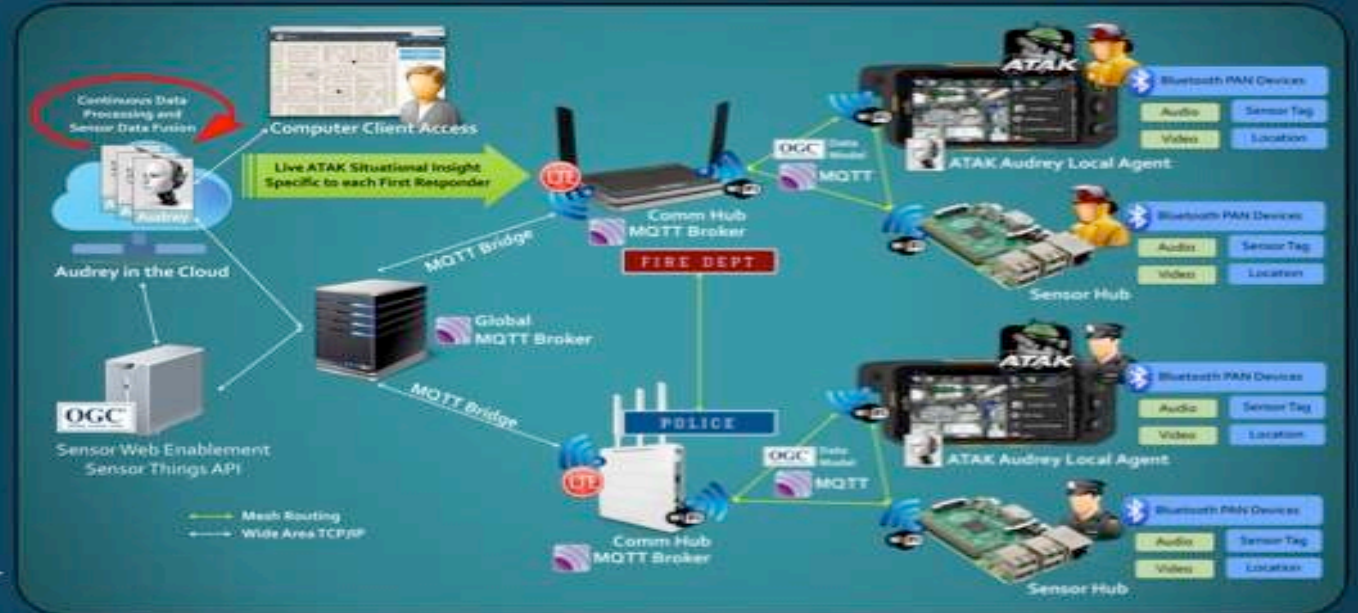
DHS S&T Next Generation First Responder (NGFR) Program

AUDREY Artificial Intelligence Agent and Internet of Things (IoT)

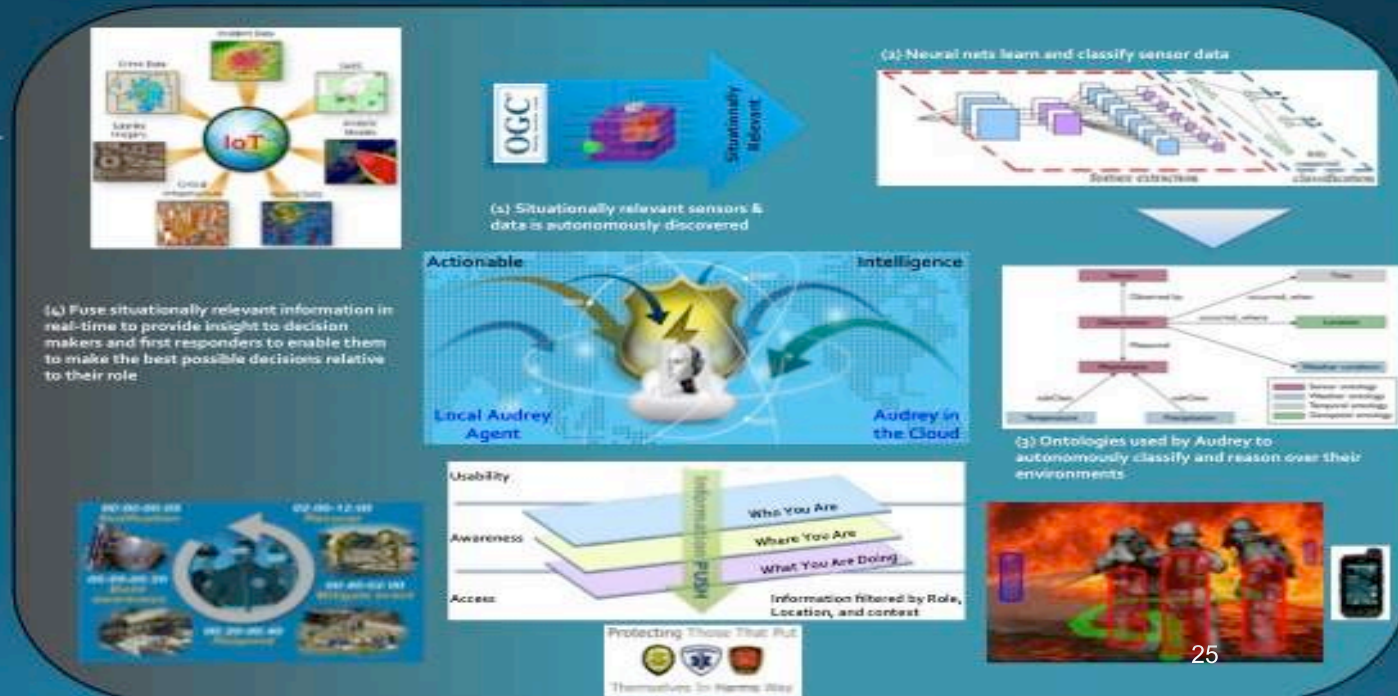
PROTECT



CONNECT



FULLY AWARE



Contacts: John Merrill, DHS Program Manager
Edward Chow, JPL Program Manager
edward.chow@jpl.nasa.gov, 818-393-3854



NEXT GENERATION FIRST RESPONDER



Thank you!